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Efficiency assessment of the Brazilian industry regarding their revenue generation and performance in safety and health management programs through DEA method

Avaliação da eficiência da indústria brasileira em relação à geração de receita e desempenho em programas de gestão de segurança e saúde através do método DEA

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ABSTRACT

After the financial crisis in the 2000’s that was dispersed by the global economy have been exposed weaknesses in the countries’ economies, which in an abundance stage were not as noticeable. This has led several governments, including from developed countries (EU and USA) to promote new economic reforms to avoid and reduce the recession impacts such as unemployment, export incomes falling and decline of the economy as a whole. The reindustrialization movements have been the main tool of most of these proposals to economy reactivation, but it is not simply reactivating obsolete and unsafe industrial plants, unlike the reindustrialization is based on the idea of creating a new industrial structure with higher productivity on the one hand, but without loss due to occupational accidents and diseases that marked the ancient and primitive industrialization cycle worldwide. Thus, in this article it is used a Data Envelopment Analysis (DEA) model as a tool in order to identify Brazilian industry's benchmarks that would share best practices in terms of revenue generation as well on health and safety performance, to assure finally more competitiveness to Brazilian industry. The benchmarks identified by DEA model should be deeply studied hereafter to characterize which of their practices would be compatible with the new and desirable reindustrialization cycle to dynamize the Brazilian economy.

Keywords: Data Envelopment Analysis; Industry Efficiency; Safety and Health Management; Revenue Generation; Reindustrialization.

RESUMO

Após a crise financeira nos anos 2000, que foi dispersada pela economia global, foram expostos pontos fracos nas economias dos países, que em uma fase de abundância não eram tão perceptíveis. Isso levou vários governos, inclusive de países desenvolvidos (UE e EUA) a promover novas reformas econômicas para evitar e reduzir os impactos da recessão, como o desemprego, a queda nas receitas de exportação e o declínio da economia como um todo. Os movimentos de reindustrialização têm sido a principal ferramenta da maioria dessas propostas para a reativação econômica, mas não é simplesmente reativar plantas industriais obsoletas e inseguras, ao contrário da reindustrialização baseada na ideia de criar uma nova estrutura industrial com maior produtividade, por um lado, mas sem perdas devido a acidentes e doenças ocupacionais que marcaram o antigo e primitivo ciclo de industrialização mundial. Assim, neste artigo, utiliza-se o modelo Data Envelopment Analysis (DEA) como ferramenta para identificar os benchmarks da indústria brasileira que compartilham as melhores práticas em termos de geração de receita e desempenho em saúde e segurança, para garantir finalmente maior competitividade Indústria brasileira. Os benchmarks identificados pelo modelo DEA devem ser profundamente estudados a seguir para caracterizar quais de suas práticas seriam compatíveis com o novo e desejável ciclo de reindustrialização para dinamizar a economia brasileira.

Palavras-chave: Data Envelopment Analysis; Eficiência Industrial; Gestão de Segurança e Saúde; Geração de receita; Reindustrialização.

1 INTRODUCTION

The relationship between operational productivity and high performance in terms of Safety and Health is an important aspect to creation of new ways to improve the economic competitiveness of the nations in the world market and to promote the welfare of their people. Understand the different cycles of the economies e how different their impacts on the developed/undeveloped countries can be, are key concepts to identify strengths and weaknesses in economies. Following will promote a discussion about these elements. It is presented the analysis of DEA method for later use in benchmark positive identification by making a clear separation of DMU most efficient among the analyzed. This is particularly important in an economic environment in which they wish to promote the resumption of growth through stimulus policies to the industrial sector which is a major generator of employment and income for the people.

2 LITERATURE REVIEW

Here are some notes about industrialization, deindustrialization and reindustrialization and their relationship to productivity and performance in terms of safety and health at work.

2.1 AN OVERVIEW ABOUT INDUSTRIALIZATION, DEINDUSTRIALIZATION AND REINDUSTRIALIZATION ECONOMIC CYCLES.

As described by Kawata (2011) the relationship between industry and economic development have been examined in various fields of study, where some of the best known this relationships are: 1) the relationship between economic development and inequality in income distribution, known as the Kuznets curve; 2) the relationship between economic development and environmental quality, known as the Kuznets environmental curve; 3) the relationship between economic development and a change in the industrial structure, known as the Petty–Clark's law. Highlighting Petty–Clark's law this one suggests that as the economy of a country develops, its proportion of primary industries declines while those of its secondary and tertiary industries increase (KAWATA 2011).

In an article discussing the why manufacture industry is so important for the economic development of the nations, Mattos & Fevereiro (2014) propose that the importance of manufacturing industry lies in the fact that their activities generate productivity gains that are later scattered throughout the economy. Not only of their own industrial structure, as well as in the activities of the primary and the tertiary sectors. Then, the manufacture industry, which is extremely dynamics, can promote the productivity, and induce the creation of jobs in other industrial areas and in activities of primary and tertiary sectors of economy.

Another aspect highlighted by Mattos & Fevereiro (2014) was the social welfare, created by the continuous process of productivity gains depend, in general, the ability to maintain economic activity or expand, and will also depend on the way these are socially distributed. The distribution of economic gains from productive activity will be the result of socio-political factors in each society at each historical moment.

As described by Tregenna (2011) the cycles of industrialization, deindustrialization and reindustrialization are a set of changes socioeconomics profiles of thehuman societies, which change the share in GDP of a country due to industrial sector, specially manufacturing sector becausethese specificitieshave special features that make it important as an 'engine of growth'.

In the industrialization cycle, as shown Hoey (2015), which had its beginning in the late nineteenth century, in most of the Western countries, there has been a deep change in the socioeconomic profile and so their economies are no more deeply dependent on agricultural production and passed a new stage of economic development, one more focused on the industrial production of goods. Industrialization was an important change that led legions of workers to abandon farming and rural areas to get higher wages in growing urban centers of manufacturing.

From the 1970s, however, it began to be evident that the industry, or secondary sector, was joining the primary sector in the decline of jobs that began to be seen in the rising service sector or the tertiary sector. That means, in most of the Western countries, mainly the more economically developed, a start of deindustrialization cycle.

According Prisecaru (2015) deindustrialization is a process of socioeconomic transformation, which involves the removal or reduction of intensive industries in energy and labor-intensive and that produces impacts in macroeconomic terms on the loss of jobs, income and exports of a country.Also, as shown by Pike (2009) deindustrialization maybe interpreted as a direct consequence of the evolution and stage of maturity of the economy and, as economies develop through this model, they evolve into more advanced forms of economic activity. Rowthorn and Wells (1987) suggested deindustrialization might be both an effect and a cause of poor economic performance.

When the manufacturing industry begins to lose share of GDP after the country attained a high per capita income, qualifies the deindustrialization as natural, positive or normal since the jobs lost with deindustrialization can be relocated to a dynamic service sector and/or sophisticated than pay high salaries and raises the standard of worker's life. As summarized by Rowthorn & Wells (1987) a positive deindustrialization accompanies full employment and rising real incomes.

When deindustrialization begins long before the country reaches this level of per capita income, deindustrialization is said to early or premature, since in that case the deindustrialization begins before there was the expansion of intensive service sector knowledge become able to absorb the labor unemployed from industry (FIESP, 2013).In the figure 1 is shown the typical changes in employment (%) and per capita income profiles over time between the different economic sectors. Also, as summarized by Rowthorn &Wells (1987) a negative deindustrialization accompanies rising unemployment and stagnant real incomes.

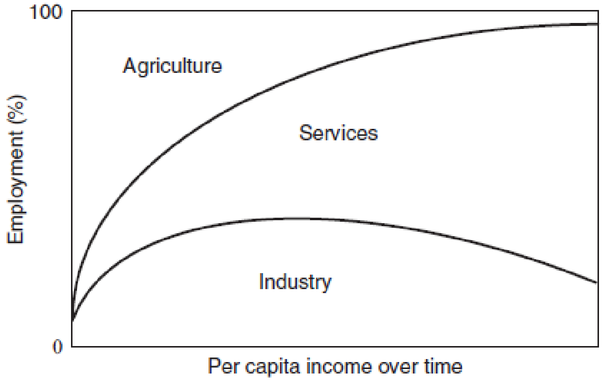

Figure 1. Typical changes in employment and GDP per capita by economic sector.

Source: Pike, 2009.

According FIESP (2013), typically, the deindustrialization process in developed countries occurred naturally when the GDP per capita of them reached an average of USD 19,500 (PPP at 2005 constant prices). In general, as described by Prisecaru (2015), the deindustrialization was not a problem until the financial crisis has seriously hit Western countries with a low share of manufacturing industry but with a high share of financial services.As proposed by Tregenna (2011) in the countries where premature deindustrialization has been trigged or exacerbated by policy-related factors such as trade of financial liberalization, the reindustrialization may be necessary.

Despite of mature deindustrialization from Europe the financial crisis broughtrecently the need of his reindustrialization. So, in March 2000 European Union adopted the Lisbon Strategy, which was replaced in 2010 by a new plan named by ‘Europe 2020’,which proposes give to the European economy a profile smart, sustainable and inclusive, based on following objectives: 1) employment; 2) innovation; 3) education; 4) social inclusion; 5) climate-energy and 6) increasing the share of manufacturing industry in the GDP to around 20% in 2020. (THE EUROPEAN COMMISION,2013).

Similarly, as response to financial crisis on American economy, in February 2013 the president of the United States of America announced a plan to make his country a magnet for jobs and manufacturing, in a clear proposition of reindustrialization of USA, based on following points: 1) Partnering with businesses and communities to invest in American-made technologies and American workers through a network of new Manufacturing Innovation Institutes; 2) Ending tax breaks to ship jobs overseas and making the U.S. more competitive; 3) Bringing jobs back, by new partnership with communities to attract manufacturers and their supply chains, especially to hard hit manufacturing towns; 4) Leveling the playing field and opening markets for American-made products. (THE WHITE HOUSE, 2013)

On the other hand, the deindustrialization in undeveloped countries, like the Brazil, typically occurred prematurely and at a very fast pace. In Brazil's case began since 1985 when his GDP per capita was only USD 7,600 (PPP at 2005 constant prices). Thecontinuous decreasing of share by manufacturing industry in Brazilian GDP, since from 1980's decade is strongly fallen as shown in figure 2.

There are some evidences, according FIESP (2013), that a reindustrialization process can induce a larger share of manufacturing in GDP and together with a high rate of investment contribute to a higher rate of economic growth, shortening the time it takes a country to double its income per capita. However, according Prisecaru (2015), an adequate reindustrialization process cannot be a simple return to outdated and inefficient industrial structures but one should start a new and qualitative industrial development focused on high technologies and supported by huge investments in human resources and research activities.

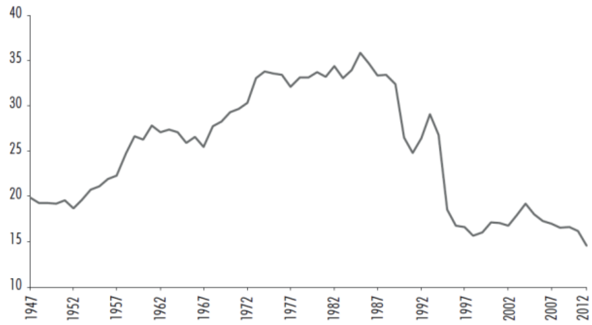

Figure 2. Share of Manufacture Industry in Brazilian GDP (1947-2012).
Source: Mattos & Fevereiro, 2014.

Regarding the situation of premature deindustrialization jointly to his recent macroeconomic performance indicate the Brazil as a country candidate to reindustrialization process, which in several aspects could be inspired in the processes in course in UE and USA.So, as shown by FIESP (2013), following a global trend, to recover his growth curve, more closely of developed countries, Brazil will need to reach an average income per capita about USD 20,000 (PPP in 2005 constant prices) and a HDI of approximately 0.809 and, a possible way to reach this goal is precisely through the strengthening of his manufacturing industry based on a new structure guided the high productivity and a strong decrease of losses, highlighting workplace accidents, occupational diseases and fatalities.

2.2 RELATIONSHIP BETWEEN HSE PERFORMANCE AND PRODUCTIVITY

Accidents have adverse effects in terms of decrease in productivity and quality, and deterioration of companies' public image or inside organizational climate. A special attention should be given to losses due to workplace accidents, occupational diseases and fatalitiesbecause the large number of those occurrences has a significant human cost for different societies and should lead to losses of economic potential and productivity for the countries, since apart from the decrease in human capital and the damage done to production equipment, a large number of working days are lost, as described by Fernandez-Muñiz et all (2009).

According Goetsh (2014) nowadays there is widespread understanding of the importance of providing a safe & healthy workplace. Mainly after the World War II, the practitioners of occupational health & safety began to see the need for increase their cooperative/integrated efforts and the more important highlights in this direction include:

a) Learn more by sharing knowledge about workplace health problems, particularly those caused by toxic substances.

b) Provide a greater level of expertise in evaluating health and safety problems.

c) Provide a broad database that can be used to compare health and safety problems experienced by different companies in the same industry.

d) Encourage accident prevention.

e) Make employee health and safety a high priority.

So, a good HSE management can have a positive effect not only on accident rates, but also on competitiveness variables and financial performance. But, is this statement really true, under viewpoint of all stakeholders? Not always, some would say. Forward will be better explained how the relationship between HSE performance and operational productivity is.

As shown by Oxenburgh & Marlow (2005), in a manufacturing that is producing solid materials (e.g.: nuts and bolts, textiles, pencils, etc.), then machine or material productivity may be measured in terms of output per hour worked. However, some kind of worker productivity may also be measured as the output that a worker makes in a unit of time and, often this isn't the case. Not rarely in some cases the only measure, of productivity is the ratio between the time paid for by the employer and the time the employee spends actively working; the productive hours.

Conceptually, the productive hours are defined as the total hours paid for by the employer less hours not actively producing over a one-year period. Among the ''non-productive'' hours, which are paid for by the employer, are included: injury (workplace) absence; illness absences; and other absences (e.g., maternity leave; military service; vacation and statutory holidays; training, etc.). Accidents and Illness work-related are elements from the most visible face of ‘‘adverse cost’’ due to time away fromwork, linked and recorded as a lost time injury. However, productive time will also be lost where workers are not able to work with total efficiency by several ways.

Analyzing the performance data on occupational accidents and diseases from Brazilian industry (BRASIL, 2014), as shown in figure 3, can be noted a strong increase of number of cases, especially due to a significant impact of the not formally notified cases, in opposition to statement of Brazilian labor law whereby, all occupational accidents should be issued a sheet to workplace accident reporting (CAT) on a mandatory basis, regardless of whether or not there was absence from work.

As studied by Veltri et all. (2007) the most companies do not make the strategic connection between occupational safety performance and financial performance. However, when is asked: “do investments in occupational safety practices contribute to operating performance?” the answer given by several occupational safety specialists and academics have been “Yes!”. Even so, occupational safety specialists need to go beyond linking of occupational safety performance to regulatory compliance performance by linking safety performance to operating performance.

The Veltri et al. (2007) study systematically examined the theory that good safety, as measured by safety perception disconnects, is related to good operating performance. Therefore, according the hypothesis, when safety perceptions are good and agreed upon by both, employee and management, operational performance should also be good. If this relationship does exist, then the subjective conclusions previously stated would be supported. Safety disconnect is a key construct in this study and, it means the difference in safety perceptions between managerial employees and operational employees. And, when this ‘disconnect’ increases the overall safety worsens. Mathematically this is modeled by the sum of the squared differences between managers and operational employees on the survey’s items about safety. Finally, were summed the scores based on the results of an exploratory factor analysis that indicated that all those safety items in the survey were part of the same underlying construct. As theory predicts, safety perception disconnect is related to many of the individual indicators of both internal and external performance.

Veltri et al. (2007) concluded, based on internal measures the hypothesis that safety is good business is supported by the data. As disconnect increases (negative safety), internal scrap and rework increases (performance gets worse). Likewise, when safety perceptions are positive, internal scrap and rework performance improves. As disconnect increases (negative safety), performance on internal reliability and durability gets worse. Likewise, when safety perceptions are positive, internal reliability and durability performance improves. Internal reliability and durability is a measure of quality describing internal measures that will show up externally at the customer. Such outcomes are in line with the core concepts of total quality management which would suggest that employees who do not feel safe in their jobs are not likely to do their jobs well.

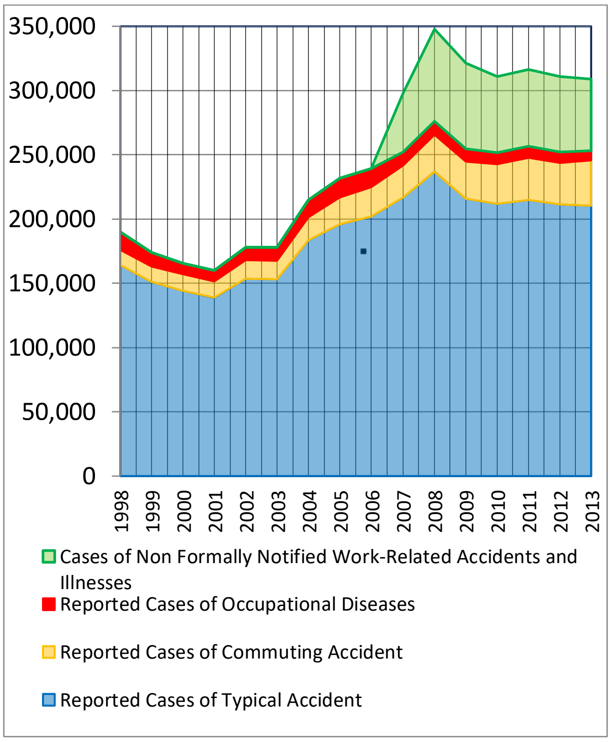

Figure 3. Number of accidents,occupational diseases and cases non-formally notified in Brazilian Industrial Sector.

Yet based on external measures, Veltri et all. (2007) concluded on the hypothesis that safety is good business is somewhat supported by the data. As safety disconnect decreases (positive safety), delivery relative to competitors improves. When safety perceptions are positive, we are faster and/or more reliable than our competitors. In addition, as safety disconnect decreases (positive safety), external costs of production improve. External costs of production are the costs of production processes relative to our competitors. A high score means that you have lower costs, so this is good (an increased score on cost of production item means that your costs are lower compared to your competitors). The data suggests that the place that top managers will notice the influence of poor safety is in their external costs compared to their competitors.

Then, the integration of safety into operations as a core value will assist the successful management of HSE as a congruent aspect of companies who are growing fastly. In a reindustrialization context seems alegitimate ideato conciliate a high productivity and high HSE performance and finally maximize business performance.

In this article will analyze a context to maximize business performance using a DEA model whichusestwo inputs (Number of industrial facilities; Number of workers at Industry), onedesirable output (Revenue generation or Value added by industry on Brazilian GDP [R$]) and two undesirable outputs (number of non-fatal work-related accidents and illness; number of fatal work-related accidents and illness).

3 THE DEA METHOD

As described by Ferreira & Gomes (2012) the Data Envelopment Analysis, widely known by DEA, is a non-parametric approach, that is, which does not subject to statistical and econometric parameterized conditions. It's an analysis method based on linear programming techniques and it's useful to estimate the boundary production possibilities. Its origin comes from Farrell's (1957) study to measure efficiency through linear programming, having initially been considered by only a few authors. Then, about two decades later, the researchers Charnes,Cooper & Rhodes (1978) published an article that created the terminology 'Data Envelopment Analysis' and proposed an input-oriented DEA model which was based on constant returns to scale, and so practically, only after publishing this article the DEA method began to take a greater interest by researchers.

The main features of Data Envelopment Analysis (DEA), according to Lins & Angulo Meza (2000) include:

a) DEA methods are different from the methods based on purely economic assessment, which need to convert all inputs and outputs in monetary units;

b) The DEA efficiency ratings are based on real data and not on theoretical formulas;

c) DEA methods generalize the Farrell's method, building a virtual single output and a single virtual input;

d) DEA methods constitute an alternative and a complement to central tendency analysis and cost benefit;

e) DEA methods consider the possibility that the outliers not only represent deviations from the average behavior, but possible benchmarks to be studied by other DMU's.

f) Unlike the parametric approaches, the DEA models optimize each individual observation in order to determine a linear frontier of parts comprising the set of Pareto efficient DMUs.

The decision-making units (DMU) are featured by performing similar tasks, using different amounts of inputs and producing different amounts of outputs. Both, inputs and outputs, can be multiple. This possibility of considering several inputs and products generating a single indicator of relative efficiency, without preset a production function, is a very powerful feature of the DEA method.

The DEA method generates an empiricefficiency border, specific to the sample studied. The units on the borderare classified as efficient and the other as not efficient. The efficiency index is calculated as a function of projection of inefficient units on the border. In classical models, two forms of projection are used:

a) Input oriented models: calculate the maximum reduction of input for a same production output.

b) Output oriented models: calculate the maximum expansion of output, given certain use of input.

3.1 THE CCR MODEL

The CCR model, initially developed as input oriented, works with the concept of proportionality, that is, any change in input results in a proportional change in the outputs. This model is a generalization of Farrell's study for multiple inputs and multiple products, in which it determines the efficiency by dividing the weighted sum of the outputs by the weighted sum of inputs. Instead of equal weight for all DMUs, the model allows the choice of weights for each variable, the way that is most favorable to him, since these weights, when applied to other DMUs do not generate a higher reason to the unit.

3.2 THE BCC MODEL

The DEA BCC model (BANKER; CHARNES; COOPER, 1984) assumes that the evaluated units present variable returns to scale. In this model, the axiom of proportionality between inputs and outputs is replaced by the axiom of convexity.

As explain Bogetoft & Otto (2010) the convexity assumption states that any weighted average (convex combination) of feasible production plans is feasible as well. This assumption is analytically convenient, and some convexity is generally assumed in economic models. Indeed, convexity is necessary for market systems with price-based coordination to work efficiently. Still, convexity is not an innocent assumption, and many attempts have been made in the DEA literature to use weaker-convexity assumptions: e.g., to only assume the convexity of input consumption sets L(y) and output production sets P(x) rather than to assume the convexity of the full set T. In small data sets, convexity has significant power.

Another important assumption in DEA model BCC is the free disposabilityassumption stipulates that we can freely discard unnecessary inputs and unwanted outputs. Except in some cases of joint production (for instance, where pollution is produced jointly with desirable outputs), this is a safe and weak assumption. Where, in the use of term weak means that it is safe to make this assumption because it will most often be fulfilled but also that it contains less power in the sense of extending the production possibility set. On the other hand, strong assumptions are the opposite. (BOGETOFT & OTTO, 2010).

And finally, but no less important is the return to scale assumptions suggests that some rescaling is possible. Different assumptions have been made regarding the extent and nature of the feasible rescaling. The weakest assumption is that there is no rescaling possible, γ=1, and the strongest is that there are constant returns to scale, $\gamma \geq 0$. No rescaling is also called variable returns to scale to produce a common terminology. In between, we may assume that any degree of downscaling is possible but not any degree of upscaling, $\gamma \leq 1$. This means that it cannot be disadvantageous to be small but that it may be disadvantageous to be large, i.e. there may be decreasing returns to scale (BOGETOFT & OTTO, 2010).

The DEA BCC model of multipliers, output oriented is mathematically expressed by:

$$\text{Max Eff}_0 = \sum_{j=1}^{s} \mathrm{v}_i . \mathrm{x}_{i0} + u^* \quad (1)$$

Subject to

$$\sum_{i=1}^{r} \mathrm{u}_j . \mathrm{y}_{j0} = 1, \quad (2)$$

$$-\sum_{i=1}^{r} \mathrm{v}_i . \mathrm{x}_{ik} + \sum_{j=1}^{s} \mathrm{u}_j . \mathrm{y}_{jk} + u^* \leq 0, \forall k \quad (3)$$

$$\mathrm{u}_j ; \mathrm{v}_i \geq 0; \ \forall j, i \quad (4)$$

$$u^* \in R \quad (5)$$

This is the DEA formulation adopted in this study aiming verify if there are inner benchmarks in Brazilian industry in terms of Revenue Generation and HSE Performance, which could be used as reference to start a wide reindustrialization process in Brazil's productive structure and lastly generate jobs and income and give dynamism for all productive chain.

4 DATA AND VARIABLES

The data presented in Table 1 are used to inputs in DEA BCC model, output oriented. The number of industrial facilities is from CNI (2015) and the number of workers at industry in the year 2013 is from Brasil (2014), include formal jobs and exclude seasonal and/or informal jobs.

Table 1. Inputs of Brazilian Industry in 2013.

Set of industrial facilities in each Brazilian federation unit	Number of Industrial Facilities	Number of Workers at Industry
AC	1,036	15,994
AL	3,308	144,202
AM	3,302	170,021
AP	701	13,688
BA	17,903	429,779
CE	14,979	347,786
DF	7,053	122,59
ES	11,578	209,476
GO	19,200	348,872
MA	4,330	106,009
MG	66,072	1,278,433
MS	5,991	132,069
MT	9,571	151,587
PA	6,847	204,325
PB	6,149	134,168
PE	14,683	397,277
PI	3,905	67,588
PR	45.988	850,492
RJ	28.468	826,19
RN	6,190	128,35
RO	3,658	82,789
RR	488	7,701
RS	51.096	891,464
SC	43,951	760,142
SE	3,240	85,359
SP	137.612	3,509,557
TO	2,325	32,658
BRAZIL	**519,624**	**11,448.566**

The data presented in Table 2 are used to outputs in DEA BCC model, output oriented. The value added by industry on Brazilian GDP is desirable output and is from CNI (2015), and the number of non-fatal and number of fatal accidents are both undesirable outputs and are all from Brasil (2014), include work-related accidents (typical and commuting) and occupational diseases, as well the non-formally notified cases and discovered by data cross-checking, all in the year 2013.

Table 2. Outputs of Brazilian Industry in 2013.

Set of industrial facilities in each Brazilian federation unit	Value Added by Industry on Brazilian GDP [R$]	Number of Non-Fatal Accidents at Industry	Number of Fatal Accidents at Industry
AC	1,031,000,000.00	421	6
AL	5,866,000,000.00	5,513	12
AM	19,304,000,000.00	5,717	16
AP	1,038,000,000.00	341	4
BA	37,004,000,000.00	8,953	43
CE	17,843,000,000.00	6,062	32
DF	8,431,000,000.00	2,346	15
ES	34,346,000,000.00	5,125	32
GO	28,372,000,000.00	7,796	53
MA	8,619,000,000.00	1,858	21
MG	103,354,000,000.00	33,739	152
MS	10,216,000,000.00	5,170	22
MT	11,421,000,000.00	5,513	32
PA	30,698,000,000.00	5,110	38
PB	7,814,000,000.00	2,573	10
PE	24,941,000,000.00	8,576	39
PI	4,230,000,000.00	1,433	13
PR	53,186,000,000.00	23,304	102
RJ	138,131,000,000.00	19,969	78
RN	8,284,000,000.00	3,169	14
RO	4,749,000,000.00	3,744	22
RR	752,000,000.00	235	4
RS	60,069,000,000.00	23,646	85
SC	50,426,000,000.00	23,233	73
SE	7,084,000,000.00	1,535	8
SP	288,624,000,000.00	102,408	298
TO	3,398,000,000.00	595	9
BRAZIL	**969,234,000,000.00**	**308,084**	**1,233**

Using data from tables 1 and 2, are assembled the structure to DEA BCC model, shown in figure 4.

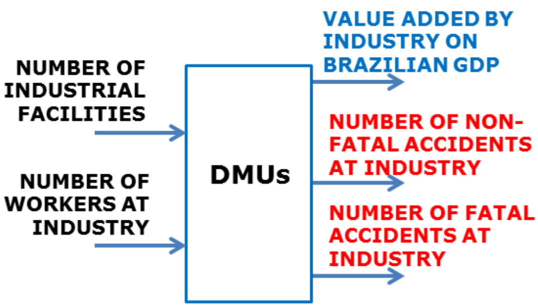

Figure 4. The DEA diagram to variables on tables 1 and 2.

In this article to DEA BCC formulation the variables are identified by following way:

k: Each one of the decision-making unit (DMU), that is, the set of industrial facilities in each Brazilian federation unit;

X_{1k}: Number of Industrial Facilities operating in each DMU;

X_{2k}: Number of Workers at Industry that are employ in each DMU;

Y_{1k}: Value Added by Industry on Brazilian GDP [R$] in each DMU;

Y_{2k}: Number of Non-Fatal Accidents at Industry in each DMU;

Y_{3k}: Number of Fatal Accidents at Industry in each DMU.

U_0: The scale factor from DEA model in each DMU;

U_1: Coefficient from DEA model to each one input variable X_{1k};

U_2: Coefficient from DEA model to each one input variable X_{2k};

V_1: Coefficient from DEA model to each one output variable Y_{1k};

V_2: Coefficient from DEA model to each one output variable Y_{2k};

V_3: Coefficient from DEA model to each one output variable Y_{3k};

Regarding the DMUs used in DEA model was considered the existing industrial park in each Brazilian federation unit, and then have been modeled 27 DMU. Despite each Brazilian federation unit has its own peculiarities and vocations for different industrial activities, it was taken over that there is enough similarity between the various studied DMUs.Also, it was admitted that all DMUs use the same inputs (facilities and workers, expressing the famous duet of capital and labor) and produce similar results in terms of revenue generation and undesirable consequences, such as work accidents and illness.

The value added by industry on Brazilian GDP is an output variable given from a report of Brazilian National Confederation of Industry (CNI) and it means, in nowadays, how strongly is the contribution of industry to generate revenues to Brazilian economy. Obviously, is expected in a possible and desirable reindustrialization scenario that this contribution will be much bigger than today.

Also, in this one DEA BCC modeling one output is the value added by industry on Brazilian GDP and, that is a desirable output, thereforecan be directly solved, however, the number of non-fatal and number of fatal accidents are both undesirable outputs and should not maximized but oppositely reduced as lower as possible. So, since maximize the mathematical inverse of a quantity is equivalent to reducing this quantity in its direct dimension, then those last two variables will be both modelled by their mathematical inverse value.

About the variables number of non-fatal and number of fatal accidents in the Brazilian industry, is also important to know that, recently, in March 2015, was issued by the Brazilian government its National Strategy to Reducing Work-Related Accidents 2015-2016 (BRASIL, 2015). Although it is a general proposition, its effects may also influence the industry's HSE performance through to reducing the losses due to work-related accidents and illness. Besides, there are some industry's initiatives in progress, like as '100% safe' the Brazilian National Program of Safety and Health at Work in the Construction Industry (in Portuguese: '100% Seguro: Programa Nacional de Segurança e Saúde no Trabalho para a Indústria da Construção'), which is mainly an educational action to awareness workers in this segment. This last one is a nationwide program of technological innovation about safety and health at work, that disseminate methods, solutions and expertise to reduce accidents and diseases at work in the construction industry. It has emphasis on prevention of fatal and disabling accidents. By an efforts conjunction mainly from government, industry and workers is expected in a reindustrialization scenario that the industry's performance in terms of safety and health will be too much better than today. In this direction, the use of DEA analysis can be help through the identifying of benchmarking that if followed can help to improve the safety and health in the whole industry.

5 RESULTS

As described by Zhu (2003) there are some quantitative models for performance evaluation and benchmarking, that including the Data Envelopment Analysis with Spreadsheets, like as MS-Excel ® and DEA Excel Solver.

So, after develop a set of 819 equations distributed in 28 MS-Excel spreadsheets to get solution by Linear Programming for DEA model, the results data are presented in table 3.

6 CONCLUSIONS

A major contribution from this study relates to the use of undesirable outputs. In a realistic industrial process always, there are desirable outputs to maximize, such as revenue generation, but also there are some undesirable outputs to minimize, like as accidents and deaths in the work. In this study it was possible see how these variables can be modeled on data envelopment analysis (DEA). The current study also was able to identify some positive benchmarks, some of which are not so apparent. Among the identified benchmarks are the following DMU: AC; AL; CE; MG; PI; PR; RS; SC; SP, all them with 100% efficiency.

Together all these DMU represent 70.8% of industrial facilities in Brazil, employ 68.7% of the Brazilian industry workers and account for 60.3% of Brazilian industrial GDP. Despite this, 71.3% of all accidents and 62.7% of deaths at work still occur in these DMU.

Table 3. DEA-BCC Results - Multipliers – Output Oriented.

DMU(k)	h(k)	u_0	$u_1 \times 10^5$	$u_2 \times 10^6$	$v_1 \times 10^6$	v_2	$v_3 \times 10^2$
AC	100.0%	0	96.53	0	88.11	0	54.95
AL	100.0%	0	0	6.93	13.02	0	283.48
AM	45.4%	0	0	2.67	4.18	1,106.85	0
AP	74.2%	0	58.40	24.27	96.34	0	0
BA	68.7%	0	0	1.60	2.50	663.02	0
CE	100.0%	0	0	2.88	5.40	0	117.54
DF	94.3%	0	11.83	0.89	11.65	42.07	0
ES	38.8%	0	2.95	0.22	2.91	10.50	0
GO	78.0%	0	3.57	0.27	3.52	12.71	0
MA	61.7%	0	6.12	3.31	11.60	0	0
MG	100.0%	0	0.78	0.38	0.80	0	2,595.04
MS	69.1%	0	9.79	0.79	9.72	34.83	0
MT	95.6%	0	9.99	0	8.71	31.40	0
PA	30.3%	0	1.97	0.82	3.26	0	0
PB	91.7%	0	10.03	2.24	12.78	3.34	0
PE	90.5%	0	0	2.28	3.57	945.27	0
PI	100.0%	0	18.47	4.13	23.54	6.16	0
PR	100.0%	0	0	1.18	1.83	0	262.65
RJ	43.4%	0	0	0.53	0.63	2,602.30	0
RN	86.6%	0	11.99	0.97	11.91	42.66	0
RO	90.9%	0	16.50	3.69	21.03	5.50	0
RR	65.1%	0	80.61	33.51	132.98	0	0
RS	100.0%	0	1.96	0	1.47	2,686.63	11.46
SC	100.0%	0	2.02	0.15	1.98	0	6.56
SE	58.6%	0	7.45	4.03	14.12	0.00	0
SP	100.0%	0	0	0.28	0.34	0	632.10
TO	73.5%	0	31.60	0	28.84	0	17.99

Surprisingly some consolidated industrial parks in Brazil had efficiencies much less than expected, among which highlighting negatively in descending order of efficiency, are the following: MS (69.10%); BA (68.70%); RR (65.10%); SE(58.60%); AM(45.40%); RJ(43.40%); ES(38.30%); PA(30.30%).

Together all these DMU represent about 15.8% of industrial facilities in Brazil, employ 19% of the Brazilian industry workers and account for 29.5% of Brazilian industrial GDP. Despite this, 17.4% of all accidents and 21.2% of deaths at work still in these DMU. For an advanced study to the future it is recommended investigate which are the factors that contribute more intensively to maximize the response of positive benchmarking.

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